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Integrated nutrient management on growth, yield and quality of okra (*Abelmoschus esculentus* L.Moench)

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ABSTRACT

A field experiment was conducted during rainy season of 2017 at the Instructional Farm, A.K.S. University, and Satna (M.P.) to study the effect of integrated nutrient management on growth, yield and quality of okra (Abelmoschus esculentus L.Moench) .Twelve treatments were evaluated in randomized block design with three replications. Amongst the INM treatments, 100% RDF (100:50:50 kg NPK ha^{-1}) with 25 kg $FeSO_4$ ha^{-1} recorded almost significantly higher growth and yield-attributing parameters, pod yield and its nutritional quality. Thus 100% RDF + 25 kg $FeSO_4$ ha^{-1} recorded maximum plant height, leaves, internodes and branches/plant, plant diameter, fresh and dry weight of plant incl;uding pod yield (145.24 q ha^{-1}), TSS (2.39^{0}Brix) as well as protein content (14.90%). The second best treatment was 100% RDF + 25 kg $ZnSO_4$ ha^{-1} (140.88 q ha^{-1} yield, 2.19 ^{0}Brix TSS and 14.70% protein). Other INM treatments having organics alone or with different proportions of NPK fertilizers were found to be less advantageous under the existing agro-climatic conditions of Satna district of Madhya Pradesh. The lowest values of all the parameters were recorded under 10 t leaf mould ha^{-1}.

Key words: Integrated nutrient management, growth, yield, quality, okra

INTRODUCTION

The long-term use of chemical fertilizers is known to degrade physio-chemical and biological properties of soil i.e. soil environment and soil health. The nutrient requirement of crops cannot, however, be met through fertilizers alone. Besides the escalating prices of fertilizers and their inadequacy calls for integration of nutrient sources for meeting the nutrient demand of crops. In fact, the balanced fertilization from different sources is referred as the integrated nutrient management (INM). Vermicompost, FYM and leaf mould etc. are the important component of INM (Tripathy and Maity, 2009 and Salvi *et al.*, 2010), The organic sources of nutrients, gaining global importance in crop production and are crop required to be integrated with chemical fertilizers. Recycling of farm by-products (organic matter) has become inevitable in the present intensive cropping system in enhancing the crop productivity and sustaining the soil health. This is eco-friendly system where as living organism are mutually benefitted and food for better health is obtained. Vermicompost being a rich source of macro and micronutrients and vitamins, plant growth regulators and beneficial microflora appeared to be the best organic source in maintaining soil fertility on sustainable basis towards an eco-friendly environment (Edwards and Arancon, 2004). Okra (*Abelmoschus esculentus* L.Moench) commonly known lady's finger or bhindi, belongs to the family Malvaceae. It is widely adopted vegetable in Indian kitchens and can be grown round the year. The different varieties of okra may respond differently under INM packages under different agro-climatic conditions. The relevant information was lacking under the agro-climatic condition of Kymore plateau of M.P., hence the present research was taken up in order to maintain the sustainable yield of okra.

MATERIALS AND METHODS

The field experiment was conducted during rainy season of 2017 at the Instructional Farm, A.K.S. University, Satna (M.P.). The soil of the experimental field was silty clay-loam having pH 7.5, electrical conductivity 0.26 dS/m, organic carbon 0.48%, available N, P_2O_5 and K_2O 186.6, 12.5 and 200 kg/ha, respectively. The total rainfall received during June to October, 2017 was 760.7 mm. The 12 treatments comprised of $\mathbf{T_1}$ 100% RDF (100:50:50 kg NPK ha^{-1}), $\mathbf{T_2}$ 20 t FYM ha^{-1}, $\mathbf{T_3}$ 5 t VC ha^{-1}, $\mathbf{T_4}$ 10 t leaf mould ha^{-1}, $\mathbf{T_5}$ 75% RDF+20 t FYM ha^{-1}, $\mathbf{T_6}$ 50 % RDF + 20 t FYM ha^{-1}, $\mathbf{T_7}$ 75 % RDF+ 10 t VC ha^{-1}, $\mathbf{T_8}$ 50 % RDF + 10 t VC ha^{-1}, $\mathbf{T_9}$ 75 % RDF + 10 t leaf mould ha^{-1}, $\mathbf{T_{10}}$ 50 % RDF + 10 t leaf mould ha^{-1}, $\mathbf{T_{11}}$ 100 % RDF +

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25 kg $ZnSO_4$ ha^{-1} and **T_{12}** 100% RDF + 25 kg $FeSO_4$ ha^{-1}. These were laid out in a randomized-block design keeping three replications. Okra variety Kashi Pragati (VRO-6) was sown @ 10 kg seed/ha in rows 60 cm apart on 10 July, 2017. The FYM and vermicompost were applied as per specified treatments. The micronutrients Zn and Fe were applied through zinc sulphate ($ZnSO_4 . 7H_2O$) and iron sulphate ($FeSO_4 .7H_2O$) as per mentioned doses. The crop was grown as per recommended package of practices. The crop was harvested in four pickings during October, 2017. The growth, yield attributes and yield were recorded at final picking. The nitrogen content in okra was estimated by micro-Kjeldahl method and the % N-content so obtained was multiplied by 6.25 to obtain protein content. The TSS was measured by hand Rafractometer (Erma, 0-32^{0}Brix).

RESULTS AND DISCUSSION

Crop growth

The application of 100% RDF + 25 kg $FeSO_4$ ha^{-1} resulted in tallest plants (152.3 cm) than the individual application of organic sources of nutrients, but was at par with the treatments 100 % RDF + 25 kg $ZnSO_4$ ha^{-1} followed by 100 % RDF and 75 % RDF+ 10 t VC ha^{-1} The results clearly indicated that okra plants fertilized with 100% RDF + 25 kg $FeSO_4$ ha-^{1} or 100% RDF + 25 kg $ZnSO_4$ ha^{-1} or 100% RDF or 75% RDF + 10 t VC ha^{-1} augmented these growth characters. The highest number of leaves, internodes and branches per plant were obtained under the treatment having 100% RDF + 25 kg $FeSO_4$ ha^{-1} and then 100% RDF + 25 kg $ZnSO_4$ ha^{-1} (Table 1). This could be attributed to nitrogen stimulation of plant growth in association with $FeSO_4$ or $ZnSO_4$. Besides, nitrogen being the major constituents of chlorophyll, protein and amino acid their synthesis could have been accelerated by the adequate supply of nitrogen from the soil. In addition, phosphorus and potassium played their unique role. These results agree with the finding of Salvi *et al.* (2010). The higher values for fresh and dry weight of plant, fresh and dry weight of pod and diameter of plant were recorded with 100% RDF + 25 kg $FeSO_4$ ha^{-1}, closely followed by 100% RDF + 25 kg $ZnSO_4$ ha^{-1}. These parameters were found lowest under sole application of leaf mould. The best results from 100% RDF + 25 kg $ZnSO_4$ ha^{-1} and 100% RDF + 25 kg $FeSO_4$ ha-^{1} may be obviously due to better vegetable growth in terms of plant height and number of branches, inclusive of whole canopy which was reflected through fresh and dry weight as well as diameter of plant.

Table 1: Growth parameters of okra under different INM treatments

Treatments	Plant height (cm)	Number of leaves/ plant	Number of internodes /plant	No. of branches/ m plant	Diameter of plant (mm)	Fresh weight of plant (g)	Dry weight of plant (g)
T_1 100% RDF (100:50:50 kg NPK ha^{-1})	145.1	26.2	17.1	2.66	18.9	368.7	138.6
T_2 20 t FYM ha^{-1}	136.0	24.0	15.4	2.26	18.6	333.6	126.7
T_3 5 t VC ha^{-1}	139.9	24.6	16.5	2.40	18.8	348.7	131.4
T_4 10 t leaf mould ha^{-1}	134.8	22.8	14.8	2.20	18.5	328.1	123.2
T_5 75% RDF+ 20 t FYM ha^{-1}	144.9	25.3	17.1	2.53	18.7	365.7	133.2
T_6 50 % RDF + 20 t FYM ha^{-1}	139.9	25.1	16.9	2.33	18.5	361.1	132.4
T_7 75 % RDF+ 10 t VC ha^{-1}	148.6	26.5	17.4	2.93	19.0	385.2	140.8
T_8 50 % RDF + 10 t VCha^{-1}	142.1	25.9	17.0	2.53	18.9	366.0	135.8
T_9 75 % RDF + 10 t leaf mould ha^{-1}	141.89	25.2	16.2	2.33	18.8	361.9	132.4
T_{10} 50 % RDF + 10 t leaf mould ha^{-1}	137.6	25.0	16.0	2.13	18.4	355.6	132.0
T_{11} 100 % RDF + 25 kg $ZnSO_4$ ha^{-1}	151.9	27.0	17.5	3.00	19.1	398.4	142.4
T_{12} 100% RDF + 25 kg $FeSO_4$ ha^{-1}	152.3	27.3	17.9	3.26	19.5	405.2	143.1
S.Em$\pm$	1.08	0.13	0.15	0.11	0.09	5.40	0.15
C.D. (P=0.05)	3.19	0.39	0.46	0.34	0.27	15.85	0.46

These results could be attributed to the appropriate release of N, P & K along with micronutrients. The pronounced effect of inorganic fertilizers with $FeSO_4$ or $ZnSO_4$ on several growth parameters might also be the evidence of increased assimilation of protoplams resulting in greater cell division, formation of more tissues and vigour of the plant.Moreover, nitrogen increases the cation exchange capacity of plant roots and that makes them efficient in absorbing other nutrients ions like phosphorus, potassium etc. Besides, N, P_2O_5 and K_2O the potential source of micronutrients like $ZnSO_4$ and $FeSO_4$ are directly involved in the enzyme systems which regulate the various plant metabolic activities. The beneficial effect of combined application of 100% NPK fertilizers plus micronutrients or organic manure on these parameters have also been reported by Ray *et al.* (2005), Srivastava *et al.* (2009) and Salvi *et al.* (2010). The application of sole organic manures had no significant effect on the growth characters due to delayed and reduced supply of nutrients for the actively growing plants.

Yield attributes and yield

Application of 100% RDF + 25 kg $FeSO_4$ ha-^{1} and 100% RDF + 25 kg $ZnSO_4$ ha^{-1} resulted in higher number of pods (19.33 to 19.66 per plant), pod length (11.66 to 11.99 cm) and fresh weight of individual pod (12.22 to 12.34 g). The lowest values for these four pod characters were recorded with 20 t FYM ha^{-1}, 5 t VC ha^{-1}, 10 t leaf mould ha^{-1} and 50 % RDF + 10 t leaf mould ha^{-1} wherein only organic manures (FYM, vermicompost or leaf mould alone) were applied (Table 2). The study clearly indicated that the efficacy of the inorganic fertilizers was pronounced when they were combined with $FeSO_4$ or $ZnSO_4$ micronutrients. Addition of micronutrients might have enhanced the efficacy of the applied N, P_2O_5 and K_2O thereby helped in improving the soil conditions for better plant growth, balanced C:N ration and thus increased the synthesis of photosynthates which could be the possible reasons for increasing the pod characters. In other treatments the incorporation of organic manure with 50 to 75% RDF might have solubilizing effect on plant nutrients as well as chelating effect on metallic ions resulting in their appropriate availability in terms of timely requirement which could be the another probable reason. Another favourable factor contributing for better pod characters might be the involvement of organic manures (FYM, VC or leaf moulds) which contained fair amount of macro and micronutrients as well as growth-promoting substances which induced better plant growth. The present findings are in agreement with those reported by Bodamwad *et al.* (2006), Salvi *et al.* (2004), Vennila and Jayanti (2008), Shrivasava *et al.* (2009) and Salvi *et al.* (2010).

Table 2: Yield-attributes, yield and quality of okra under different INM treatment

Treatments	No. of pods /plant	Length of pod (cm)	Diameter of pod (mm)	Fresh weight of pod (g)	Dry weight of pod (g)	Total pod yield (q/ha)	Total soluble solids (^{O}Brix)	Protein content (%)
T_1 100% RDF (100:50:50 kg NPK ha^{-1})	18.6	11.4	16.4	11.6	4.56	137.4	1.99	14.5
T_2 20 t FYM ha^{-1}	16.0	10.6	15.8	10.6	3.86	125.3	1.64	13.8
T_3 5 t VC ha^{-1}	16.4	11.1	15.9	10.8	3.99	128.9	1.83	13.8
T_4 10 t leaf mould ha^{-1}	15.7	10.5	15.5	10.4	3.72	122.2	1.76	13.7
T_5 75% RDF+ 20 t FYM ha^{-1}	17.7	11.1	16.0	11.3	4.10	132.5	1.95	14.3
T_6 50 % RDF + 20 t FYM ha^{-1}	17.4	11.0	15.9	10.9	4.05	130.8	1.89	14.0
T_7 75 % RDF+ 10 t VC ha^{-1}	18.8	11.6	16.9	11.8	4.66	139.9	2.02	14.6
T_8 50 % RDF + 10 t VCha^{-1}	18.0	11.4	16.3	11.3	4.24	134.1	2.00	14.1
T_9 75 % RDF + 10 t leaf mould ha^{-1}	17.5	11.0	15.9	10.9	4.05	130.6	1.86	14.1
T_{10} 50 % RDF + 10 t leaf mould ha^{-1}	16.8	10.8	15.8	10.7	4.00	130.3	1.77	13.9
T_{11} 100 % RDF + 25 kg $ZnSO_4$ ha^{-1}	19.3	11.6	17.1	12.2	4.72	140.8	2.19	14.7
T_{12} 100% RDF + 25 kg $FeSO_4$ ha^{-1}	19.6	11.9	17.2	12.3	4.91	145.2	2.39	14.9
S.Em$\pm$	0.15	0.07	0.03	0.10	0.05	0.52	0.01	0.05
C.D. (P=0.05)	0.44	0.22	0.10	0.32	0.15	1.53	0.04	0.15

Okra plant fertilized with 100% RDF with 25 kg $FeSO_4$ or $ZnSO_4$ (T_{11} and T_{12}) proved most favourable which resulted in total pod yield (140.88 to 145.24 q ha^{-1}) and proved significantly superior over other INM treatments. The treatment consisting of organic manure alone (20 t FYM ha^{-1}, 5 t VC ha^{-1} and 10 t leaf mould ha^{-1}) registered lower pod yield of okra (122.26 to 128.97 q ha^{-1}) indicating that the use of organics along was insufficient for fulfilling the requirement of total nutrition of the plants. The higher pod yield might be due to the higher production of dry matter, height of plant, branches and pods per plant. All these factors are very closely related to the crop yield. Increased foliage might have resulted in production of more photosynthates enhancing the yield potential. The other reasons may be the additive effect of organic manures along with 50 or 75% RDF which might have provided better soil conditions inclusive of improved soil fertility, mineralization of nutrients, enhanced the efficacy of applied N and P; enhanced the activities of microbes and also release of growth stimulants and many more. Perhaps the efficacy of the inorganic fertilizer might have pronounced when these were applied with micronutrients. The favourable effects of Zn and Fe (applied through $ZnSO_4$ and $FeSO_4$) on fruit yield may be ascribed to their involvement in the synthesis of tryptophan a precursor or the growth-promoting substances and also in many metallic enzyme systems. Their effects may be in maintaining an optimum balance of plant nutrition for better growth as well as favourable effect on retention of flowers in okra. The other bio-parameters which could have helped in increase of yield were synthesis of carbohydrates and their translocation to the potential storage organs through better growth and more number of pods per plant (Reddy *et al.*, 2001). Similar results were reported by Solanki *et al.*, 2018 and Singh and Singh (2017) in onion and cabbage, respectively. The sole organic manures and leaf mould failed to express any significance. This might be due to the different rate of mineralization, availability and utilization of plant nutrients from organic manures.

Quality parameters

The higher values of TSS (2.19 and 2.39 ^{o} Brix) were observed in the combination of 100% RDF + 25 kg $ZnSO_4$ ha^{-1} and 100% RDF + 50 kg $FeSO_4$ ha^{-1}, respectively. However, the TSS was comparatively higher (2.0 to 2.02 ^{O} Brix) in an organically produced okra pods in 75 % RDF+ 10 t VC ha^{-1} and 50 % RDF+ 10 t VC ha^{-1} when compared to only inorganic produced pods (100% RDF). The pods of okra plants, produced with 20 t FYM ha^{-1} recorded the lowest value of TSS (1.64 ^{o} Brix). The favourable effects on higher TSS under 100% RDF + 25 kg $ZnSO_4$ ha^{-1} and T_{12} (100% RDF + 25 kg $FeSO_4$ ha-^{1}) treatments could be due to the positive response of okra to micronutrient application. The vigorous plant growth, resulted in efficient production of photosynthetic products and thereby might have developed healthy pods. Moreover, the application of Zn and Fe might have regulated various metabolic activities of plants which are involved in the auxin production. These are also vital for the oxidation processes in plant cell and helps in the transformation of carbohydrates and regulates sugars in plant (Singh and Singh, 2017). The best role of iron is its catalytic function in nutrient absorption and balancing other nutrients and also in biological oxidation and reduction and other metabolic processes in plants. It may also be associated with organic acid metabolism. It is directly involved in the protein synthesis (Pal *et al.*, 2016).

The higher crude protein (14.70 to 14.90%) was found with 100% RDF +Zn SO_4 or $FeSO_4$ which was followed by other combination of 75% RDF + 10 t VC ha-^{1} (14.60%) and then 100% RDF only. The increase was pronounced in the higher level of inorganic form applied in combination with micronutrients favoured by intense protein synthesis and its efficient storage in the present of abundant supply of available nitrogen. Similar results were obtained by Bodamwal and Rajput (2006), Vennila and Jayantiz (2008), and Salvi *et al.* (2010).

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